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NATIONAL BUREAU OF STANDARDS

Technical News

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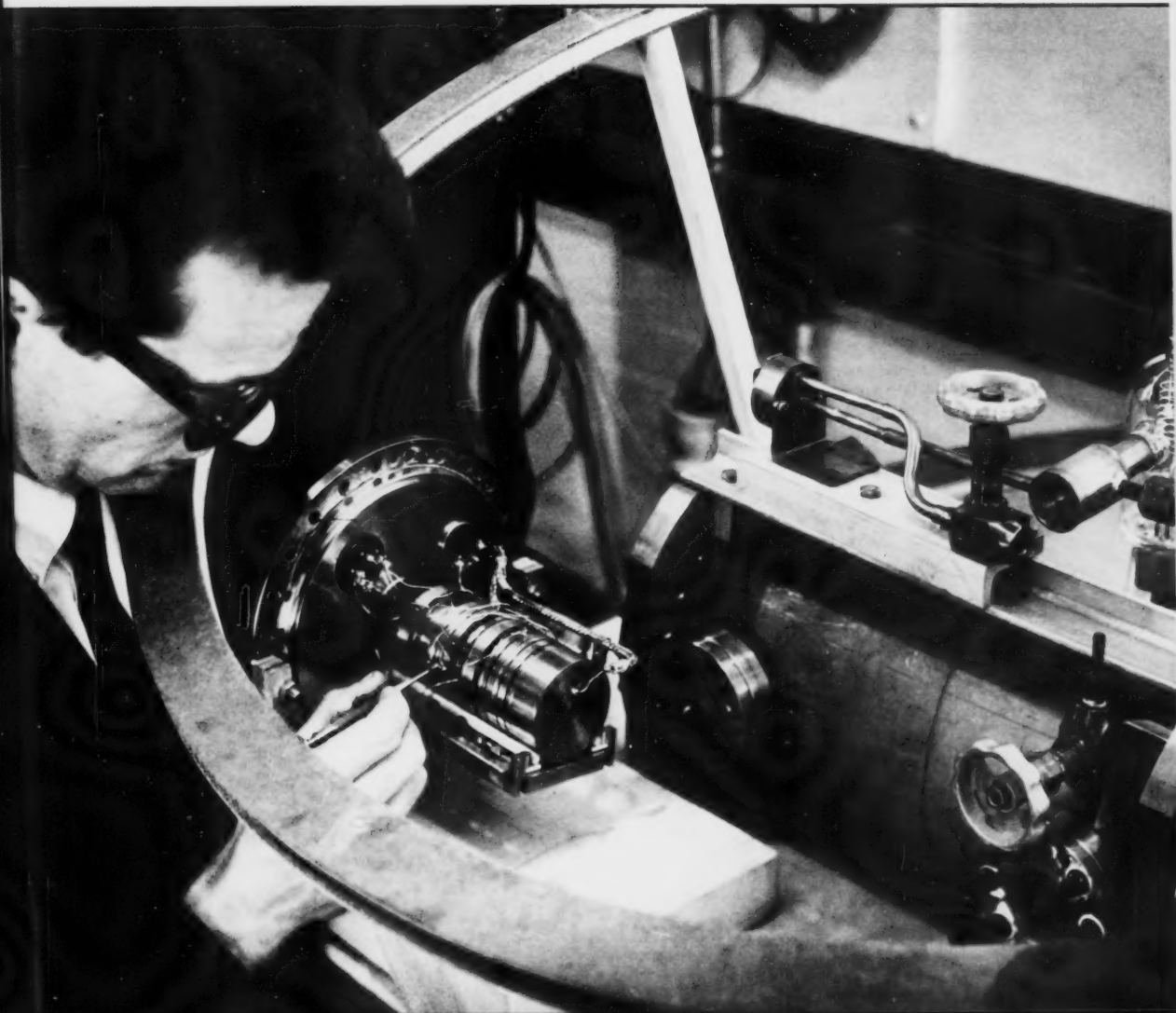
DETROIT

BULLETIN

VOLUME 48

FEBRUARY 1964

NUMBER 2





U.S. DEPARTMENT OF COMMERCE

LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
Subscription price, domestic \$1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use
of funds for printing this publication approved by the Director of the Bureau of the Budget (June 19, 1961).

Library of Congress Catalog Card Number: 25-26527

February 1964

Issued Monthly

Vol. 48, No. 2

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COVER: J. Arol Simpson positions one of the lens elements of an electron gun designed to pass the maximum possible number of low-voltage electrons through a given space. Because they give a current at low voltages at least an order of magnitude higher than previously attainable, these guns will enable scientists to perform experiments considered impossible until now. The assembly in the photo, which includes elements used in evaluating gun performance, will be mounted within the adjacent vacuum chamber for testing. The Helmholtz coils protect the test area from interfering magnetic fields. (*For details, see p. 27.*)

Multistaged Low-Voltage Electron Guns

ELECTRON guns designed at the Bureau under partial sponsorship of the Advanced Research Projects Agency will enable scientists to perform experiments until now considered impossible. Objective of the designers, J. Arol Simpson and C. E. Kuyatt, was to provide a means for passing the maximum possible number of low-voltage electrons through a given space. This objective is embodied in multistaged guns¹ that give a current at low voltages at least an order of magnitude higher than previously attainable. Two guns producing highly collimated beams and spanning the range from 1 eV to 5 keV were assembled and evaluated as illustrations.

Data obtained in laboratory studies of various interactions among electrons and gas atoms are necessary to the interpretation of such astrophysical phenomena as stellar temperatures, electron densities, and the effective dielectric constant of a gas. The success of these laboratory experiments depends upon proper simulation of actual conditions, such as maintaining as many gas atoms or molecules as possible in an excited state within a given space. This requirement often can be met with an electron beam of small diameter and large length-to-diameter ratio operated at an energy that favors excitation of the gas atoms. Such a favorable energy must be a small multiple of the desired excitation energy, for electrons at higher energies pass through the gas without interacting strongly enough with the atoms. Typical excitation energies of interest lie between 1 and 100 eV.

The beam profile and the electron density at any given energy are governed by basic physical limitations. There are two well-known limitations: One results from the space charge repulsion of the charged particles; the

other, relating energy densities, is of an essentially thermodynamic nature. In the case of electron guns, it has not always been taken into consideration that these two limitations—in addition to acting separately—act in combination.

The usual procedure in designing electron guns is to choose the desired operating parameters: final electron energy (beam energy), final spot size, and convergence angle. Then, for any set of values of these parameters, the equations governing the limitations on space charge and energy density (brightness) will be satisfied if the brightness at the cathode is sufficiently high.

The point that has often been overlooked in such designs is that the brightness at the cathode, because of the space charge limitation on the cathode, is itself a function of the beam parameters. In conventional guns, this relation between cathode brightness and beam parameters is such that when the beam energy is below a certain value, the cathode brightness will fall below that which is required.

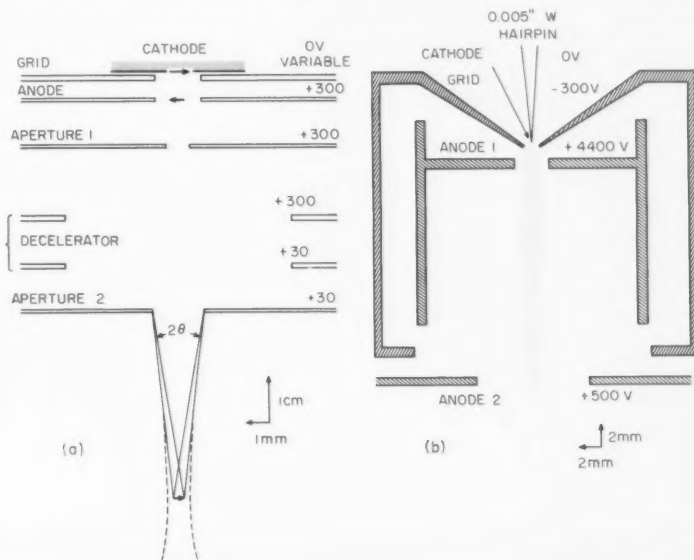
In such a case, the desired brightness can be obtained only through multistaging.² In the Bureau's designs, the procedure was to establish a high electric field at the cathode by using an intermediate anode at high voltage, and then to decelerate the electrons to the required final energy. This procedure effectively dissociates the two basic limitations so that each may be taken into account separately.

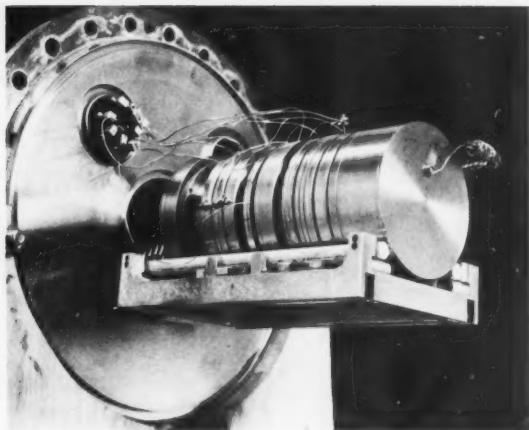
Thus, the problem of design of low-voltage electron guns can easily be separated into two parts: that of the extraction stage and that of the deceleration stage. The two design segments can be considered almost as though they were independent and can be assembled of time-proven electron-optical elements. Many of the proper-

These electrode configurations illustrate the type of designs developed at the Bureau for multistaged electron guns. These guns will pass the maximum possible number of low-voltage electrons through a given space.

(a) Operating parameters: convergence angle, 0.03 rad; operating voltage, 30 V; maximum current, 7.3 μ A; spot size, 0.1 cm at 4 cm from last gun element.

(b) Operating parameters: convergence angle, 0.003 rad; operating voltage, 500 V at 30 μ A; spot size, 0.15 cm at 40 cm from last gun element.





Closeup view of low-voltage electron gun and test assembly. The first five elements at the left constitute the gun structure; the remaining elements are used in performance evaluation. The gun elements and the test elements are so made that they can be mounted on ceramic rods. Thus various elements in one instrument can be easily interchanged at will. Also, any element may be used in various of the Bureau laboratories that utilize this form of assembly.

ties, such as spot size and convergence angle, are to a large extent individually adjustable.

The principle of multistaging has been employed previously, but with objectives different from those of the present designers. In several cases, the first anode was operated at lower voltages than those of the final beam in order to achieve more nearly laminar flow or less noise, or to obtain superior telefocus lens properties together with a high brightness value.

One of the two guns built as illustrations of the NBS design developments was operated at voltages from 1 to 200 eV. It was designed to give a spot size of 0.1-cm diam at a distance of 4 cm from the last gun element, with a maximum convergence angle of 0.03 radian. The other gun was designed to operate at higher voltages and to give a beam of 30 μ A at 500 V into a 0.15-cm-diam spot at 40 cm from the last gun element, with a convergence angle of 0.003 radian.

¹For further details, see Limitations on electron beam density of unipotential electron guns at low voltages, by J. Arol Simpson and C. E. Kuyatt, *J. Res. NBS* **67C** (Eng. & Instr.), No. 4, 279-281 (1963); and Design of low voltage electron guns, by J. Arol Simpson and C. E. Kuyatt, *Rev. Sci. Instr.* **34**, No. 3, 265-268 (1963).

²In some gun designs, a third stage in the form of a focusing lens may be necessary.

Wait Appointed Senior Research Fellow



Dr. James R. Wait, internationally known authority in the field of radio propagation, has been appointed a Senior Research Fellow at the Bureau. Dr. Wait has been on the staff of NBS Boulder (Colo.) Laboratories since 1955, and will continue to serve as consultant to Dr. C. G. Little, Chief of the Central Radio Propagation Laboratory at Boulder.

A 1959 recipient of the Department of Commerce Gold Medal for highly distinguished authorship in the field of radio propagation, Dr. Wait has to his credit two books and more than 200 other technical publications. In 1960 he received the Boulder Scientist Award from the Research Society of America. In 1962 he was one of three Bureau staff members who received the new Samuel Wesley Stratton Award established by the Bureau to recognize outstanding contributions by NBS scientists.

Born in Ottawa, Canada, Dr. Wait entered the radio propagation field as an Army radar technician during World War II. After the war he received three degrees from the University of Toronto, a B.A.Sc. in engineering physics in 1948, an M.A.Sc. in the same field in 1949, and a Ph.D. in electromagnetic theory in 1951. During this time he was associated with Newmont Exploration, Ltd., of New York and Jerome, Ariz. From 1952 to 1955 he was a section leader in the Defence Research Telecommunications Establishment in Ottawa and was primarily concerned with electromagnetic problems. Since joining the Bureau in 1955, Dr. Wait has concentrated on the theoretical aspects of radio propagation. He was the first editor of the Radio Propagation Section of the NBS Journal of Research (1959-61), now published monthly under the title *Radio Science*.

Dr. Wait is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), and past president of the Boulder Chapter of the Research Society of America. He is a member of the U.S. National Committee of the International Scientific Radio Union (URSI) and the Administrative Committee of the Professional Group on Antennas and Propagation of the IEEE. In 1961 he was appointed Professor (adjoint) of the Electrical Engineering Department of the University of Colorado. In 1960, he was a visiting research fellow at the Technical University of Denmark, in Copenhagen.

POINT DEFECTS IN RUTILE AND THORIA

Effects on Mechanical and Electrical Properties

NBS SCIENTISTS are studying the physical properties of crystalline refractory oxides by theoretical methods and experimental techniques. In this work, they are investigating imperfections such as dislocations and point defects, and the effects these imperfections have on the physical properties of crystalline solids. Recently J. B. Wachtman, Jr., and his co-workers completed an investigation concerned with point defects in which both the mechanical and electrical properties of thoria (ThO_2) and the mechanical properties of rutile (TiO_2) were measured and compared. The resulting data are in good agreement with theoretical equations relating crystal properties to defects; they thus provide a convincing check on the theory.

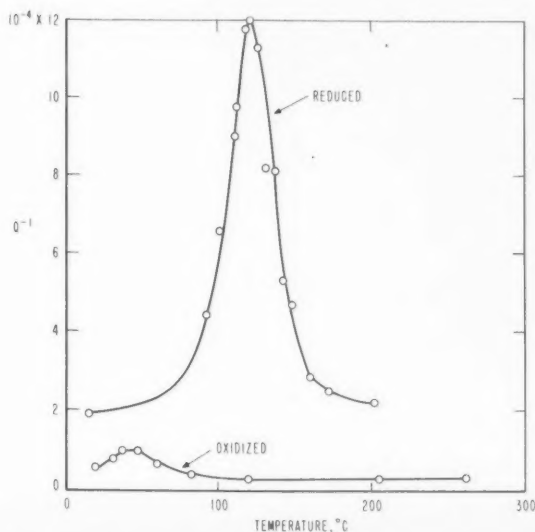
Pure crystalline solids have their atoms arranged in periodic patterns. In a crystal at equilibrium at absolute zero their periodic arrangement will be perfect, apart from small zero-point vibrations of atoms about their average positions. However, at all temperatures above absolute zero, varying degrees of disorder among the atoms cause interstitial atoms and atomic vacancies to be present. Both of these defects are usually present in crystals; however, there is always a tendency for one or the other to predominate because their energies of formation are usually unequal.

Imperfections may affect the technological properties of a material, such as its sinterability or machinability, and many physical properties of solids are dependent to some degree on purity and perfection.¹ A knowledge of the possible point defects, their motions, and factors controlling their concentration is therefore

necessary for the development of sound ceramic technology.

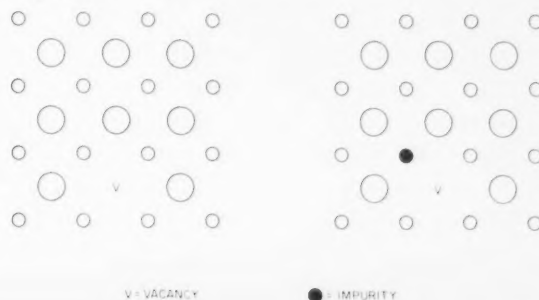
In this Bureau study, the frequency and temperature dependence of the mechanical (internal friction, elastic moduli) and electrical (dissipation factor, dielectric constant) properties of nearly pure oxides and oxides having known amounts of impurities were determined. Particular point defects cause peaks to appear on some of the curves determined in these measurements. By quantitatively comparing the experimentally obtained curves with those based on theoretical models, a model structure can be confirmed and numerical values for jump frequencies and activation energies can be calculated. These values are useful in predicting the movements of vacancies and interstitial atoms in the crystal.

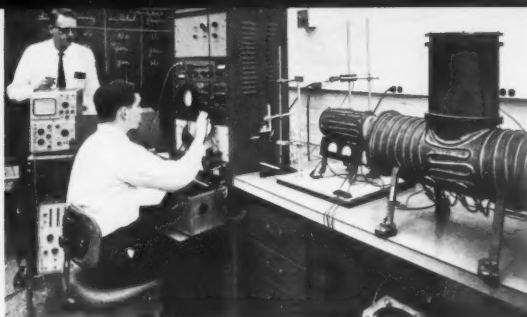
The type of model employed depends upon which of two types the defect is thought to be. The first type is characterized by freedom of a vacancy defect to move throughout the crystal by successive jumps; the second type is characterized by freedom of the vacancy to jump about only in the neighborhood of a trapping center, such as an impurity ion. Each of these types of point defect is thus limited by the set of sites in the crystal which it can occupy. The theoretical analysis in either case is simplified by considering the symmetry of the sites.² For the first type, the sites make up a structure extending throughout the crystal and thus space group-symmetry operations underlie the analysis,³ but point group operations can be used to simplify the treatment (see footnote 2). For the second type, because the sites are clustered about the point occupied by the trapping center, point group-symmetry operations un-



Left: Internal friction (Q^{-1}) peak resulting in a reduced rutile crystal rod with its axis oriented parallel to the crystallographic *a*-axis. After heating the rod in an oxidizing atmosphere, the lower curve was produced, indicating that titanium interstitials (resulting from vacuum reduction) cause internal friction peaks in rutile.

Below: Two types of point defects are illustrated in two-dimensional drawings of crystalline planes. The vacancy defect (*left*) can move from one site to another throughout the crystal. The vacancy in the neighborhood of the impurity ion (*right*) can move only about that trapping center.





derlie the analysis and are directly used.^{4,5}

Studies of defects of the first type were carried on by the Bureau with rutile (TiO_2) crystals. Heating rutile in a vacuum causes a loss of a small fraction of the oxygen atoms, thus forming oxygen vacancies or titanium interstitials—both defects of the first type. By analyzing the effect of elastic strain upon the space group operations possessed by the rutile structure, predictions were made as to whether or not an internal friction peak should be caused by either defect for several crystal orientations.⁶ The peaks observed in the experiments fit the orientation dependence predicted for the titanium interstitial; no peaks caused by oxygen vacancies were observed.

Rod-shaped single crystals of rutile were employed in the analysis. For a single rutile crystal having its axis parallel to the crystallographic a -axis, the theory indicates that oxygen vacancies should not cause a peak; but that titanium interstitials, occurring either as isolated interstitials or as pairs of interstitials, should. The theory predicted further that no internal friction peak should be found for a rod with its axis parallel to the crystallographic c -axis. Rods of both orientations were reduced in vacuum to introduce the point defects and internal friction was measured using a flexural resonance apparatus.⁷

A peak was found at 121 °C and 1838 c/s with the rod parallel to the a -axis, but no peak was found with the other rod. Subsequent heating of the a -axis rod removed the point defects introduced by the previous reduction and the internal friction peak vanished as expected. Measurements were then made on a rod with its axis perpendicular to the c -axis and at 45° to an a -axis. The theory indicates that for this orientation a peak should be found for isolated interstitials but not for pairs. The measurements following vacuum reduction showed no peak. Although the results suggest that pairs of titanium interstitials are the predominant point defect introduced by vacuum reduction of rutile, this conclusion should not be accepted as final until further experiments can be carried out over a wider range of temperatures and the results fitted into one consistent theory.

To study the second (limited jump) type of defect, thoria (ThO_2) containing calcium oxide (CaO) in small amounts (up to 1.5 percent) was chosen (see footnote 4). The most probable type of point defect for this structure was predicted to be an oxygen vacancy for each calcium atom. The vacancies, electrostatically attracted to the Ca ions at moderate temperatures, are in nearest-neighbor positions to a Ca ion. As there

J. B. Wachtman, Jr. (left) and T. Fridinger (center) make flexural measurements of rutile crystals. The specimens are held at the desired temperature (20 to 600 °C) in the furnace (right) and are oscillated at particular frequencies. The crystal resonates and any changes in the physical properties of the crystal are detected electronically and recorded. From these data, values for such properties as internal friction are calculated.

are eight equivalent nearest-neighbor positions, each oxygen vacancy could occupy any one of eight positions at the corners of a cube surrounding a Ca ion. If an alternating stress or electric field is applied, the motion of the vacancy among the eight positions can no longer be completely random because the vacancies will attempt to follow the driving forces.

The problem is similar to that of a molecule exposed to infrared radiation; absorption will occur if the frequency of the radiation matches one of the optically active vibration modes of the molecule. These vibration modes are analogous to the relaxation modes for the sites accessible to the vacancy. A peak in the internal friction curve will occur at the temperature at which the frequency of a mechanically active relaxation mode is equal to the frequency of a sinusoidal stress. A peak in the dissipation factor will occur at the temperature at which the frequency of an electrically active relaxation mode is equal to the frequency of a sinusoidal stress.

Detailed analysis leads to the conclusion that for any given temperature the frequency of the electrically active modes is equal to half the frequency of the mechanically active modes. Thus, the results of an electrical experiment should show a dissipation factor peak at a frequency half that of a mechanical experiment that shows an internal friction peak, provided the experiments are conducted at the same temperature.

Such experiments using sintered polycrystalline specimens showed good agreement between the peak temperatures; both peaks were absent for specimens containing no Ca. The results leave little doubt that introducing CaO into ThO_2 causes oxygen vacancies to form.

¹ Impurity controlled properties of ionic solids, by A. D. Franklin in *The Physics and Chemistry of Ceramics*, pp. 77-109 (Gordon and Breach, New York, 1963).

² Symmetry splitting of equivalent sites in oxide crystals and related mechanical effects, by J. B. Wachtman, Jr., H. S. Peiser, and E. P. Levine, *J. Res. NBS* **67A**, No. 4, 281-289 (July-Aug. 1963).

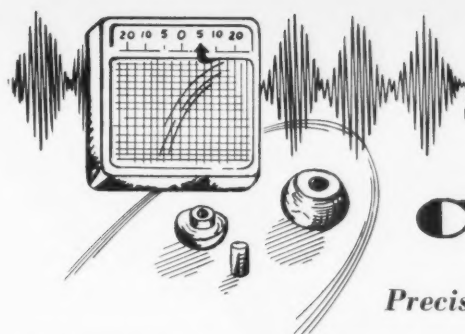
³ Reduction of space groups to subgroups by homogeneous strain, by H. S. Peiser, J. B. Wachtman, Jr., and R. W. Dickson, *J. Res. NBS* **67A**, No. 5, 395-401 (Sept.-Oct. 1963).

⁴ Mechanical and electrical relaxation in ThO_2 containing CaO, by J. B. Wachtman, Jr., *Phys. Rev.* **131**, No. 2, 517-527 (July 1963).

⁵ Relaxation modes for trapped crystal point defects, by A. D. Franklin, *J. Res. NBS* **67A**, No. 4, 291-292 (July-Aug. 1963).

⁶ Internal friction in rutile, by J. B. Wachtman, Jr., and L. P. Doyle, in preparation.

⁷ A method for determining mechanical resonance frequencies and for calculating elastic moduli from these frequencies, by S. Spinner and W. E. Tefft, *Proc. ASTM* **61**, 1221-1238 (1961). Also, see Accurate computation of elastic moduli by improved resonance frequency technique, *NBS Tech. News Bull.* **47**, 1-3 (Jan. 1963).



STANDARDS AND CALIBRATION

Precision of the U.S. Frequency Standard

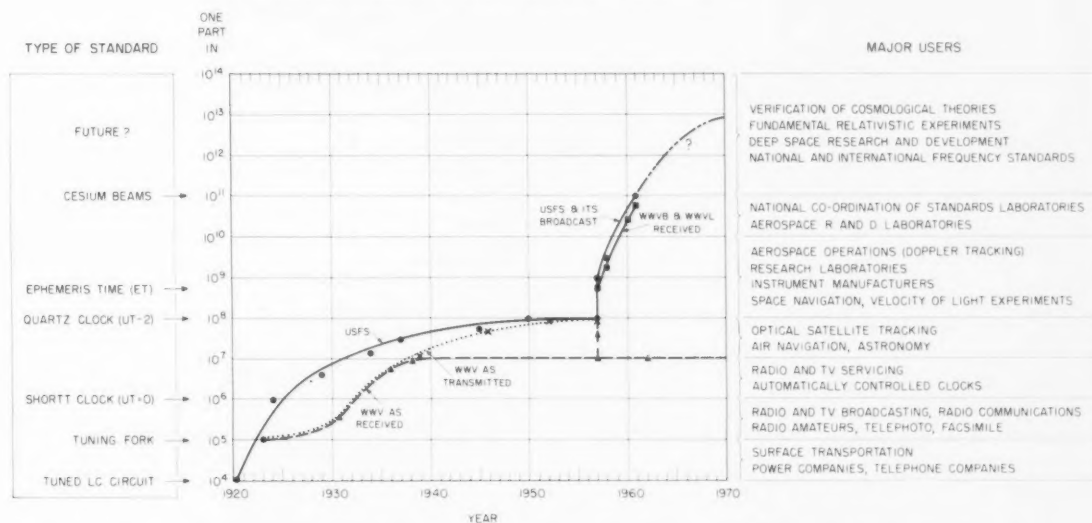
THE BUREAU has maintained the United States Frequency Standard (USFS) since 1920, and since 1923 has made the standard available through the high-frequency broadcasts¹ of station WWV, now located at Beltsville, Md. A companion HF station (WWVH, Maui, Hawaii) was established in 1948 to provide wider coverage, and new facilities were recently put in operation for low-frequency stations WWVB and WWVL² Ft. Collins, Colo., to assure reception on a global basis.

Research and development over the years have resulted in vast improvements in the precision of the USFS, and in the stability of the broadcast signals. In the figure below, the solid line represents the improvements in the precision of the USFS. The sharp upward turn in 1957 reflects the conversion to an atomic frequency standard. The present standard, a cesium beam maintained at the NBS Boulder (Colo.) Laboratories, is precise to 2 parts in 10^{12} , a precision much higher than that achieved in the measurement of

any other quantity. One to two parts in 10^{13} are attainable for measurement times of about 10 hr. Work is in progress at Boulder on a cesium standard that should provide about twice the precision of the present standard; on a thallium beam that to date has provided the same precision as the standard and can perhaps improve on the accuracy of the cesium beam by a factor of 10; and on a hydrogen maser that represents a potential increase in precision by a factor of 10.

The dotted line in the figure represents the stability of WWV (and WWVH after 1948) as transmitted. Since 1957, the stability of all broadcast signals has been essentially that of the USFS. The dashed line shows the stability of the WWV and WWVH signals as received. The leveling off of the signals as received at about 10^7 , despite great increases in the stability of the broadcast signals, results from inherent limitations imposed on the signals by ionospheric instabilities.

IMPROVEMENTS IN THE PRECISION OF THE U.S. FREQUENCY STANDARD (USFS) AND ITS DISSEMINATION



Improvements since 1920 in the precision of the U.S. Frequency Standard, and in the precision of the broadcast and received signals of NBS standard radio stations. From 1957 on, the precision of the broadcast signals matches that of the Frequency Standard. At the left are listed the various frequency standards used over the years, and at the right the level of precision required by different users.

Low-frequency stations WWVL and WWVB provide a much higher received accuracy than WWV and WWVH because of the difference in the modes of propagation. High-frequency signals are propagated by successive reflections between the earth and the ionosphere. Changes in the composition and height of the ionosphere create instabilities in the propagation of these signals, and degrade the received accuracy. Low-frequency signals, on the other hand, are propagated directly from source to receiver, ducted between earth and ionosphere, and are degraded very little during propagation.

¹ NBS Misc. Publ. 236, Standard frequencies and time signals from NBS stations WWV and WWVH, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, price 10 cents.

² See New facilities dedicated for WWVB and WWVL, NBS Tech. News Bull. 47, 178 (Oct. 1963).

New NCSL Officers

The National Conference of Standards Laboratories recently held an election by mail ballot. Results of the election are as follows:

Chairman: A. J. WOODINGTON, General Dynamics/Astronautics.

Vice Chairman: W. G. AMEY, Leeds & Northrup.

Recording Sec./Treas.: H. W. LANCE, NBS Boulder (2-yr. term).

General Committee:

H. C. BIGGS, Lockheed Missiles and Space.

O. E. LINEBRINK, Battelle Memorial Institute.

S. C. RICHARDSON, General Electric.

C. E. WHITE, AVCO R.A.D.

L. B. WILSON, Sperry Gyroscope.

I. G. EASTON, General Radio, continues as Corresponding Secretary until September 30, 1964, at which time the terms of the above officers, with the exception of Mr. Lance, also expire.



Astin Receives Rockefeller Award

Dr. Robert F. Goheen (right), President of Princeton University, presents NBS Director Dr. Allen V. Astin with a 1963 Rockefeller Public Service Award. Dr. Astin was cited as a senior career government employee who has "made outstanding contributions to the nation" through his work. (See p. 23 in the January 1964 *Technical News Bulletin*.)

new dates for

Conference on Precision Electromagnetic Measurements

The 1964 Conference on Precision Electromagnetic Measurements will be held June 23, 24, and 25 at the NBS Boulder (Colo.) Laboratories. These new dates are a week later than the dates originally announced in the September 1963 *Technical News Bulletin*.

The aim of the Conference is the advancement of measurement, throughout the coherent frequency spectrum, at levels of precision and accuracy appropriate to the national standards laboratories of the world. The scope of the Conference ranges from measurement studies in the traditional fields of low frequency, high frequency, and microwaves, to physical studies which may have application to future precision measurements or which may require new measurement standards. Traditionally, the Conference program also includes survey articles prepared by leading men in the field. These articles are designed to encourage a close relationship between the persons in the standards laboratories and the physicists who are making the discoveries upon which further accuracy and precision are founded. By stimulating unity among these areas the sponsors hope to shorten the interval between discovery and application in the field of precision measurement.

Since the 1962 Conference there have been two changes in the sponsorship of the Conference. Two traditional sponsors—the Instrumentation Division of the American Institute of Electrical Engineers, and the Professional Group on Instrumentation and Measurement of the Institute of Radio Engineers—have combined to form the Professional Technical Group on Instrumentation and Measurement of the Institute of Electrical and Electronics Engineers (IEEE). At the same time Conference sponsorship has been expanded to include the U.S. Commission I, Radio Measurement Methods and Standards, of the International Scientific Radio Union.

As in the past, the Conference wishes to encourage international participation. There are few, if any,

other conferences with the same objectives; yet there is a need to exchange such knowledge on a global basis and also to actively support and advance international standardization in the electromagnetic area.

Call for Papers

Original papers in the following areas will be considered for presentation: (1) atomic frequency and time, (2) determination of conductivity and complex (tensor) electric and magnetic susceptibilities, (3) direct-current and low-frequency measurements, (4) radiofrequency, microwave, and millimeter wave measurements, (5) quantum electronics in precision radio and optical measurements, (6) electromagnetic measurements for space navigation and exploration, and (7) statistical methods, automation, and data reduction in precision measurements.

As before, it is planned to publish a conference record by including the conference papers in one issue of the IEEE Transactions on Instrumentation and Measurement.

Papers should be submitted to:

Charles F. Hempstead
Bell Telephone Laboratories, Inc.
Murray Hill, N.J.

These should be in the form of 200-word abstracts. The deadline for submission of summaries is March 15, 1964.

Notifications of acceptance or rejections will be mailed by March 30, 1964. (This late deadline was chosen to allow presentation of the most recent work.) The full technical program will be announced about April 15, 1964.

General questions concerning the Conference should be addressed to:

James F. Brockman
National Bureau of Standards
Boulder, Colo. 80310.

New Book on Measurement of Very High Pressures

High-Pressure Measurement, edited by A. A. Giardini of the U.S. Army Electronic Research and Development Laboratory and Edward C. Lloyd of the National Bureau of Standards, deals with new techniques and laboratory results in the measurement of pressures in the range up to 500 kilobars (7,500,000 psi). The book (420 pages, \$10.95, Butterworth, Inc., Washington, D.C., 1963) contains the 24 technical papers and discussions, together with the record of a panel session, of the Symposium on High-Pressure Measurement held in New York City in November 1962. This symposium was arranged by the ASME Research Committee on Pressure Measurement, of which Mr. Lloyd is Chairman.

The scope of the book is indicated by a survey of some of the titles, which include: Some possible fixed points for calibration above 100 kilobars; Measurement of shock pressures in solids; A redetermination of the freezing pressure of mercury using improved apparatus and technique. Three of the papers were by NBS staff members, active in the high-pressure field: An analysis of pressure and stress distribution under rigid Bridgman-type anvils, by J. W. Jackson and M. Waxman; High pressure microscopy, by A. Van Valkenburg; and Correlation of factors influencing the pressures generated in multi-anvil devices, by J. C. Houck and U. O. Hutton.

CONJUGATE PHENOMENA

INDIRECT evidence gathered over a period of many years has indicated that the sun is a source of charged particles possessing a wide range of energies. Until recently, however, no detailed knowledge was available concerning the nature of the particles, their energy spectra, and their interactions with the earth's magnetic field and upper atmosphere.

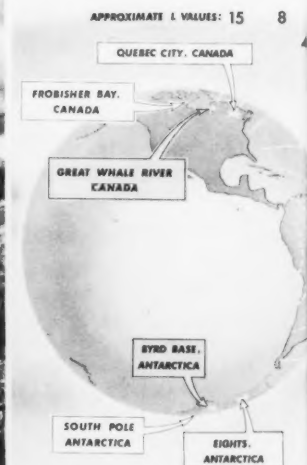
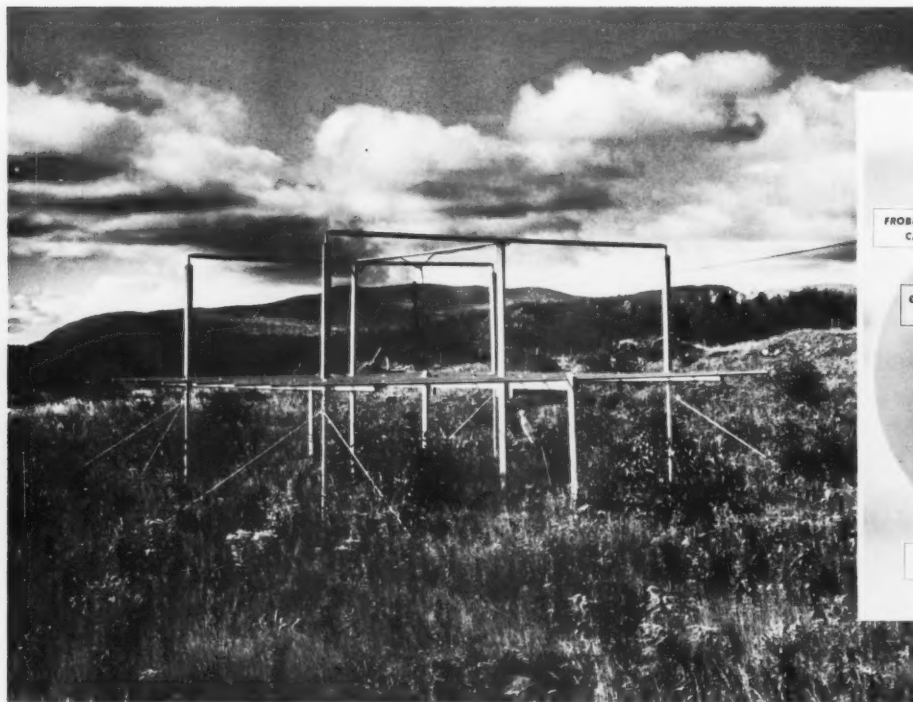
As a result of satellite observations and theoretical studies, it is now known that the sun continuously emits a stream of low-energy protons and electrons—the so-called solar wind. Occasionally violent eruptions occur on the sun. These solar flares result in an enhanced emission of charged particles, some of which possess extremely high energies. Those particles reaching the vicinity of the earth are influenced by its magnetic field and tend to travel along the terrestrial lines of magnetic force. Such particles, either protons or electrons, move along field lines in spirals that become tighter and tighter as the particles approach the surface of the earth; finally the spirals reverse and the particles move back along the field lines at increasing speed. This action is repeated at the other end of the field lines, with the result that such particles shuttle from one hemisphere to the other every second or so. This oscillation can continue indefinitely under steady conditions.

Particles "trapped" by the earth's magnetic field in this manner constitute the Van Allen radiation belts. It appears likely that at least the outer portion of these belts is populated by particles of solar origin, although

definite proof of this is not yet available. It is known, however, that during certain solar disturbances these trapped particles precipitate from their normal path and penetrate deeply into the earth's ionosphere. Most are stopped by collisions with air molecules and atoms at heights ranging from about 50 to 150 km (31 to 93 mi). The collisions between the incoming particles and the constituents of the upper atmosphere result in phenomena which can be observed by equipment located on the surface of the earth.

The NBS Central Radio Propagation Laboratory has been investigating these phenomena in order to increase man's knowledge of atmospheric physics and

Left: The height at which radio waves are absorbed in the ionosphere. This is done by use of riometer antennas, such as the one above the heavy snowpack common in that area. Center: Rehearsal of three lines of the earth's magnetic field, these measurements during the coming year. The data obtained will show the earth and of conjugate phenomena, which often show similar patterns. antenna at the Baie St. Paul, Canada, field site consists of dipole stretched across a framework. Comparison of the four simultaneous readings.



GATE POINT NOMENA

of conditions affecting radio propagation. Studies of the descending particles and the processes involving them are especially significant if conducted simultaneously at both ends of a magnetic field line, at what are known as conjugate points. One station of each pair is north of the magnetic dip equator and the other to the south of it. The instruments installed at each point record the effects of both the normal oscillation of the particles between the hemispheres and their precipitation into the earth's atmosphere.

The Bureau conducted a pilot conjugate point experiment during December 1961 and January 1962. A network of stations was set up in an accessible part of

ed in the sphere is measured at each of the conjugate point station such as the at Baie St. Paul, Canada, mounted on legs to raise it Center: Red stations at conjugate points, one at each end (Canada magnetic field these stations will record a variety of radio, airglow, and mag- data obtain will add to the knowledge of processes taking place above how similar patterns at both locations on each magnetic line. Right: New consists of dipoles, each in a corner reflector formed of parallel wires for simultaneous readings indicates the extent and movements of the absorb-

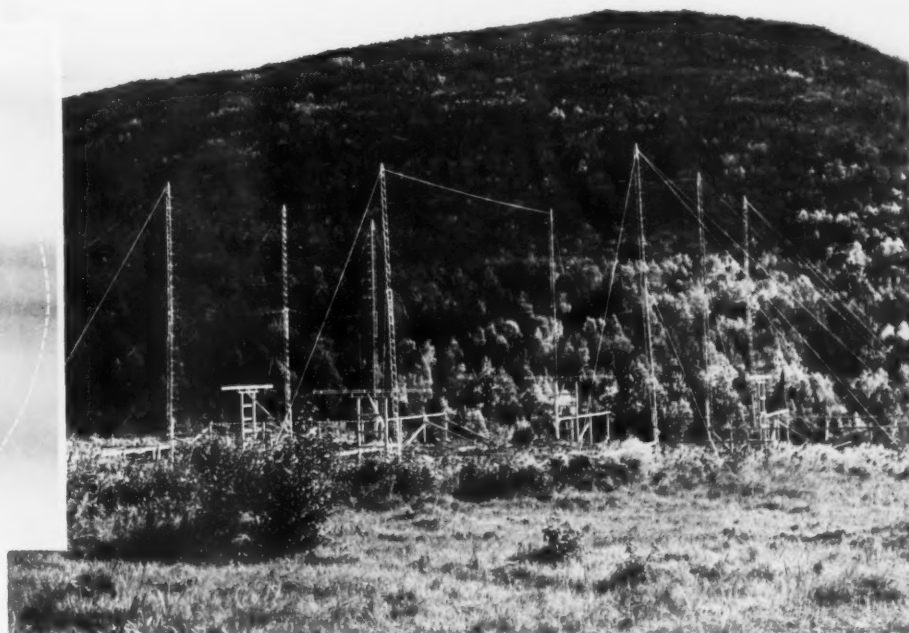
Canada near Quebec City, and a small base in Antarctica at a place computed to be conjugate to the center of the Quebec complex. This new Antarctic base became known as Eights Station.

The equipment set up for the initial experiment included a riometer (relative ionospheric opacity meter), which determines the amount of absorption experienced by radio waves arriving at the earth from outer space. This absorption takes place in the lower regions of the earth's ionosphere and is related to the incidence of the particles on the upper atmosphere.

Another experiment made use of a radio receiver tuned to a broad range of very low frequencies. This equipment picks up radiofrequency emissions from the trapped particles as they accelerate along the field lines. It is also sensitive to signals which originate in terrestrial lightning storms and are propagated between hemispheres along the magnetic field lines.

In another experiment, the ionosonde was used to probe the ionosphere by a radar technique. Magnetometers were also installed at the stations to measure the changing currents which flow in the ionosphere at the time of disturbances.

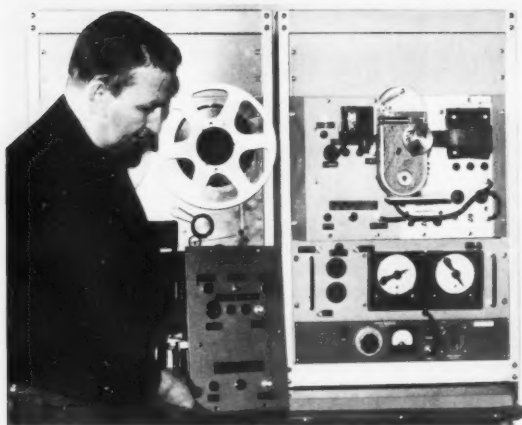
Although the preliminary experiment was in operation for only about 2 months, much information was gathered. The data obtained show that the conjugate points were in general very close to the predicted locations and that the conjugate relationships were very similar and could be localized in some instances over areas measured in only tens of kilometers. Curiously,



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Radio "hiss" is recorded at conjugate points in studies of radio propagation. Mark Andrews shows the hiss recorder designed and built at the Bureau.

however, effects at the conjugate locations were very different after the onset of a magnetic storm on one occasion.

In order to study the nature of conjugate effects more closely, a more extensive program has been prepared to operate during 1963 and 1964. This period will

provide an opportunity to study some features which are expected to vary with the season of the year.

The operation of additional pairs of stations over a range of latitudes will make apparent changes in conjugate relationships which depend on the latitude of the stations. The Eights and Quebec City stations have been reactivated. Two additional pairs of stations have been instrumented: Byrd Base, Antarctica, and its conjugate, Great Whale River, Canada; and South Pole, Antarctica, with its conjugate, Frobisher Bay, Canada. One pair of these stations will be in the highly disturbed auroral zones, while the others will be respectively inside and outside these zones.

The range of experiments conducted in last year's program will be extended with the installation of some additional equipment in the new network of stations. One piece of equipment will be sensitive to rapid changes—micropulsations—of the earth's magnetic field. Another will permit measurement of the intensity of the optical emissions of the sky, thought to be caused by the bombardment of the atmosphere by energetic particles released from the trapped zones.

The environment surrounding the planet Earth is of a highly complex and dynamic nature. It is expected that results obtained from conjugate point experiments will add to our understanding of the processes taking place about the earth and make possible further studies of the relationships among the phenomena observed.

Documentation Symposium

A Symposium on Statistical Association Methods for Mechanized Documentation will be held March 17 to 19, 1964, at the Bureau. The Symposium, sponsored by the NBS Research Information Center and Advisory Service on Information Processing (RICASIP), and the American Documentation Institute, will review the state of the art of the application of statistical association methods to mechanized documentation systems. The following topics will be covered:

Pioneering Applications of Statistical Association Techniques in Documentation
Information Retrieval and Search Renegotiation
Statistical Association Methods and Citation Indexing
Automatic Assignment Indexing
Automatic Classification and Categorization
Future Prospects.

For further information, contact

Mary Elizabeth Stevens
 National Bureau of Standards
 Washington, D.C. 20234.

Thermal Radiation Symposium to be Held in March

A Symposium on the Thermal Radiation of Solids will be held March 4 through 6, 1964, at the Sheraton-Palace Hotel in San Francisco, Calif. The meeting, fifth of its kind to be held in this country, is sponsored jointly by the National Bureau of Standards, the National Aeronautics and Space Administration, the U.S. Air Force, and the University of California at Berkeley, host for the meeting. General chairman for the event is J. C. RICHMOND of the Bureau; program chairman is DR. R. E. GAUMER of the Lockheed Missiles and Space Company.

The purpose of the Symposium is to bring engineers, physicists, and representatives of other disciplines together to share research ideas and experiences involving thermal radiative phenomena. An understanding of these phenomena is necessary to predict, measure, and control interior spacecraft temperatures that are governed by radiative heat transfer.

Twenty-eight technical papers will be presented during four sessions of the Symposium entitled Funda-

mentals of Thermal Radiative Transfer, Measurement Techniques, Environmental Effects, and Engineering Applications. An additional session, Surface Effects, will be conducted as a modified panel discussion. DR. E. U. CONDON, Professor of Physics at the University of Colorado and former Director of the National Bureau of Standards, has been invited to be guest speaker at the Symposium.

All persons attending the Symposium are required to register. Those registering during the months of January and February will receive preprints of the papers to be presented. Programs, registration blanks, and other information may be obtained from William D. Harris, Symposium on Thermal Radiation of Solids, Engineering and Sciences Extension, University Extension, University of California, Berkeley, Calif. 94704. Inquiries regarding published proceedings should be directed to Dr. S. Katzoff, National Aeronautics and Space Administration, Langley Research Center, Langley Field, Va. 20546.

NBS-Developed Dental Handpiece Presented to Smithsonian

At the request of the Smithsonian Institution, the original dental contra-angle turbine handpiece was formally presented by NBS to the U.S. National Museum. It will be placed in the permanent exhibit on dentistry in the recently opened Museum of History and Technology. The presentation was made by Dr. I. C. Schoonover, NBS Deputy Director, who was Chief of the Dental Research Section at the time of the invention in 1951. Mr. Frank A. Taylor, Director of the Museum of History and Technology, received the historic instrument for the Institution.

This original instrument was developed from the ideas of Dr. Robert I. Nelsen of Rockville, Md., while he was a Research Associate of the American Dental Association at the Bureau. Mr. Carl E. Pelander and Mr. John W. Kumpula of the Bureau assisted in perfecting and constructing the mechanical design. From this original instrument have been developed the high-speed turbine dental drills now used by dentists throughout the world. In the photograph, Taylor (*center*), Kumpula (*left*), and Nelsen examine the handpiece.



Symposium on Natural Ultra-Low-Frequency Electromagnetic Fields

A SYMPOSIUM on Natural Ultra-Low-Frequency Electromagnetic Fields (30 c/s to 0.001 c/s) will be held at Boulder, Colo., August 17 through 20, 1964. It will be sponsored by the NBS Central Radio Propagation Laboratory and by the National Center for Atmospheric Research.

The program will be divided into four sessions, the first three devoted to papers invited from panel members and the fourth made up of contributed papers. Leading scientists in this field are expected to offer papers.

The opening session, entitled, "The Environment," will cover three topics: the quiet and disturbed boundary of the magnetopause and transport of energy through this boundary; the composition and variations of the magnetosphere; and the quiet and disturbed conditions of the ionosphere.

The second session, "The Theory of EM Sources," will deal with the magnetosphere resonance in existing boundary conditions and resonance implications, and with hydromagnetic propagation, its general conditions, and its specific application to magnetosphere in the ultra-low frequencies. Other papers in the session will be on hydromagnetic propagation within the ionosphere, absorption of energy in transmission through

the ionosphere, and currents which lead to field fluctuations on the earth's surfaces. Still others will be devoted to earth-ionosphere resonances related to the Schumann cavity mode resonances and ULF field perturbation by high-altitude nuclear explosions.

"Field Observations," the third session, will consider Schumann resonances in the 7 to 8 c/s band and its harmonics as well as the unique features, polarization, region coherence, world distribution, and solar activity dependence related to regular oscillations having periods near 1 sec, 5 to 30 sec, and 1 to 7 min. The types of events associated with particle bombardment in ionospheric absorption, special regional effects—equatorial, auroral zone, conjugate point, and solar eclipse paths—will be discussed. A resumé of the latest techniques of instrumental recording will close the session.

The last of the four sessions will be a forum dealing with papers selected by the forum chairman from short contributed papers.

Further information regarding the ULF Symposium is available from either Dr. W. H. Cambell of the National Bureau of Standards or Dr. S. Matsushita of the National Center for Atmospheric Research, both at Boulder, Colorado, U.S.A.

Candela Adopted by Congress as Name of Unit of Luminous Intensity

A RECENT Act of Congress (PL 88-165, signed 4 November 1963) changed the *name* of the unit of luminous intensity from candle to candela (abbreviated cd). This action should bring usage in this country into conformance with that of the rest of the scientific world. The size of the unit was not affected by this action.

The International Committee on Weights and Measures agreed in 1946 to new definitions of the units of electricity and of light, to go into effect 1 January 1948. In anticipation of this action, legislation was introduced in the U.S. Congress to alter the legal definitions of the electrical units and to adopt legal definitions of the unit of light. The unit of luminous intensity (luminous intensity is commonly called candlepower) was defined by both the International Committee and Congress as $\frac{1}{60}$ of the luminous intensity of 1 cm² of a blackbody at the temperature of freezing platinum (1769 °C IPTS). The name selected for this unit

for international usage was *candela*, the Latin word for candle, but in conformity with common usage in this country it was translated as candle and incorporated into law.

As international usage of the term *candela* grew, it became obvious that possible confusion would be lessened if a common terminology were employed. As an example of the ambiguity that has grown up, the Bureau has been using candle on its domestic calibration reports, but *candela* in reports to the International Bureau of Weights and Measures and all other laboratories abroad. Furthermore, the Illuminating Engineering Society of this country has been using *candela* since 1959. To clarify this situation, the Bureau backed legislation which resulted in the change to *candela* and which should bring about uniformity of usage. (The recommended pronunciation for *candela* is kan·del'·á in conformity with U.S. custom in preference to adhering to the Latin in which the *e* is pronounced ä.)

Brady To Head National Standard Reference Data Program

DR. EDWARD L. BRADY has been appointed Chief of the Office of the National Standard Reference Data Program at the Bureau. He will be responsible for the direction of the National Standard Reference Data System (NSRDS), which was established at the Bureau in June 1963 by the Office of Science and Technology acting on a recommendation of the Federal Council for Science and Technology. The NSRDS program, which will coordinate a large part of the present data compiling activities of a number of Government agencies, will provide critically evaluated data in the physical sciences on a national basis.¹

Dr. Brady, who has specialized in physical chemistry and radiochemistry, comes to the Bureau from the General Atomic Division of General Dynamics Corporation. Born in Charleston, S.C., he was educated at the University of California at Los Angeles (B.A. and M.A. in chemistry) and Massachusetts Institute of Technology (Ph.D. in physical chemistry). He has authored many publications on various radiochemical and physical-chemical topics. He is a member of the American Chemical Society, the American Nuclear Society, the American Physical Society, the American Association for the Advancement of Science, and the New York Academy of Sciences.

Dr. Brady began his professional career in 1942 as a research assistant at the University of Chicago's Metallurgical Laboratory. From 1943-46 he was a research associate at Clinton Labs, Oak Ridge, Tenn. (now Oak Ridge National Laboratory). From Oak Ridge he went to M.I.T., where he held a similar position for 2 years. During the years 1948-59 he carried out a variety of assignments involving atomic energy for the General Electric Company. For 2 years during this period he was on a leave of absence to serve as U.S. Atomic Energy Commission Representative to the United Kingdom, stationed in London, England. In

July 1959, Dr. Brady became the senior scientific advisor for the United States Mission to the International Atomic Energy Agency in Vienna, Austria. He left IAEA in the fall of 1961 to become Assistant Chairman of the Chemistry Department in the General Atomic Division of General Dynamics Corporation.

The National Standard Reference Data System will consist of a National Standard Reference Data Center at the Bureau, and various other Standard Reference Data Centers in other Government agencies and at universities, research institutes, and other non-Government organizations. In order for such centers to be a part of the NSRDS, they will be required to meet general standards established by the Bureau. The independent operational status of existing critical data projects will be encouraged and the formation of new projects will be promoted.

The NSRDS will be conducted as a decentralized operation across the country, with central coordination by the Bureau. According to present plans, the data input will come from scientists in many different locations who will comprehensively review the literature in their fields of specialization and will critically evaluate the data it contains. The evaluated data will be disseminated through a series of services tailored to user needs in science and industry. In choosing work to be undertaken, the Bureau will be assisted by an Advisory Board, interagency panels, expert consultants in the subject-matter areas, and working committees of the scientific and engineering societies and industry associations that are active in the field of critical data.

¹ The aim of the NSRDS is to develop a storehouse of standard reference data to assist in the advancement of science, technology, and the national economy. This result is to be achieved through a broad-based, comprehensive effort by scientists both in and outside government.

Gammon, Wilson Appointed to Staff

MR. HOWARD GAMMON, a specialist in computer systems analysis and management analysis, and DR. RAYMOND E. WILSON, physicist, administrator, and former NBS staff member, have been appointed to the Bureau staff. Mr. Gammon's title is Assistant to the Director for Data Processing. He will advise and assist Director Allen V. Astin and other NBS staff members in the cooperative development of standards of practice in the field of information processing. Dr. Wilson will be Assistant to Dr. Irl C. Schoonover, Deputy Director for Technological Standards and Services at NBS. Dr. Wilson will direct his efforts toward strengthening the Bureau's program in technological standards.

Mr. Gammon comes to the Bureau from the Data Systems Division of the Office of the Secretary of De-

fense, where he served as a computer applications systems analyst from August 1955 to the present. His many responsibilities with OSD included membership in a 12-man material-management data systems study group charged with designing a long-range master plan and procedure for ADP application to all aspects of material management throughout the entire Department of Defense. After the group had completed its work, Mr. Gammon was given the task of determining the need for data-processing services by each element of OSD, and of recommending a plan for obtaining such ADP services.

Prior to his connection with the Department of Defense, Mr. Gammon had held progressively responsible

administrative and management planning assignments with the Federal Government.

Born in Danville, Va., Mr. Gammon received a B.A. from George Washington University, an M.A. from American University, and carried on further graduate studies at Harvard Business School.

Dr. Wilson comes to the Bureau after 8 years with the Hughes Aircraft Company, where he was manager of the Engineering Services Laboratory, Mobile Medium Range Ballistic Missile Division. His responsibilities there included environmental testing, parts qualifications, and materials and processes investigations, as well as extensive administrative functions.

Dr. Wilson was an NBS staff member from 1947-54. He joined the Bureau as physicist in the Temperature Measurements Section of the Heat and Power Division. He became Chief of that Section in 1950, and in 1951

became Assistant Chief of the Heat and Power Division, retaining also the duties of Section Chief.

Born in Salem, Oreg., in 1915, Dr. Wilson received a B.A. in physics in 1937 at Reed College in Portland, and a Ph.D. in physics from the University of Washington in Seattle in 1942. During World War II he worked for the U.S. Navy in Seattle. He was responsible for designing installations of submarine detectors on ships, supervising the installations, and testing and adjusting them during field trials of vessels. From 1944-46, as senior physicist in the Navy Degaussing Office (Seattle), he directed the development of methods of protecting ships from magnetic weapons.

In 1946 Dr. Wilson joined the faculty of George Washington University in the District of Columbia as an associate professor of physics, which post he held until being appointed to the Bureau staff in 1947.

Idealized Design Solutions for Choking Two-Phase Flow

STUDIES of choking two-phase flow in cryogenic systems have been made at the Bureau, and design recommendations, based on these studies, have been presented in graphic form.¹ R. V. Smith of the Cryogenic Engineering Laboratory carried out the studies on hydrogen, oxygen, nitrogen, and refrigerants 11 (CCl_3F) and 12 (CCl_2F_2).

Choking two-phase flow is defined as a Mach 1 condition of a liquid-gas mixture at the discharge of a constant-area device or in a flow restriction in a system such that further reduction of downstream pressure will not increase the mass rate of flow. The increasing use of liquefied gases for space, medicine, refrigeration, and other industrial and scientific purposes has increased the demand for design data for two-phase flow. Power and refrigeration systems, cryogenic transfer lines, missile propulsion systems using cryogenic fluid as a propellant, and heat exchangers are typical examples of systems where choking two-phase flow will occur.

A literature search at the Bureau revealed a large quantity of empirical data on water two-phase flow and a good understanding of choking single-phase flow in gases, but no data for choking two-phase flow in cryogenic fluids. The work undertaken at the Bureau was aimed at solving the problems of predicting whether or not choking will occur in a system, and of determining the rate of choking flow.

Choking two-phase flow can be described in terms of pressure, P ; quality ($\frac{\text{wt of vapor}}{\text{wt of mixture}}$), X ; and flow (mass per unit of time per unit of area), G . Certain

combinations of these parameters cause choking. If any two are known, the third can be calculated in a lengthy operation using formulas employing property values of the fluids. Validity of these formulas has been established by comparison of experimental and theoretical results for fluids on which empirical data are available. Using these formulas and an electronic computer, Mr. Smith calculated the choking flow rate for three cryogenic fluids and two commonly used refrigerants at intervals throughout the operable range and at various qualities of two-phase mixture. These values are presented in graphical form. This makes it possible for a design engineer, who can determine or estimate the P and X or any two of the parameters of his system, to read the third from the graph instead of making a lengthy computation.

Upper and lower limits of choking flow combinations of P , X , and G were established by selection of extreme-case models. The results of computation using these models were verified by graphical comparison with experimental data. A design engineer can determine upper and lower limits for choking flow rates from the prepared graphs. He can avoid choking by designing so the combination of P , X , and G falls below the lower choking limits. If he wishes to ensure choking, he can design his system for flows above the upper choking limits.

Of course, the combination of P , X , and G parameters might fall between the upper and lower choking limits without the systems encountering choking flow. The present state of the art is such that parameters causing choking two-phase flow can not be precisely determined.

A homogeneous, metastable model was assumed to provide upper limit choking values for the very low-quality states for all flow patterns. A system in thermal equilibrium, with separate-phase flow that would experience only vapor choking, was assumed to provide the upper limit at higher qualities. A homogeneous, thermal equilibrium model was used as the lower choking limit for the entire range of liquid-vapor mixtures. Accordingly, all solutions are idealized and the values are approximations for design guides rather than precise indicators.

Despite the limitations imposed by idealized solutions, this work provides information of sufficient accuracy for many engineering studies and the charts

save the designer from performing lengthy computations. In addition, the literature summary provides a state of the art analysis through review of available literature. It points up a need for experimental two-phase flow data on fluids other than water and the need for better instrumentation to determine the degree of metastability and flow patterns for single-component, liquid-vapor flow.

¹ Choking two-phase flow literature summary and idealized design solutions for hydrogen, nitrogen, oxygen, and refrigerants 12 and 11, by R. V. Smith, NBS Tech. Note 179 (Aug. 3, 1963). Available for 75 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Radio Science Presents Symposium Papers

The January 1964 issue of *Radio Science*, the new name for the Radio Propagation Section (Section D) of the *NBS Journal of Research*, is devoted entirely to papers presented at a VLF Symposium held at the NBS Boulder Laboratories on August 12, 13, and 14, 1963. The symposium dealt with current research in the terrestrial propagation of very-low-frequency radio waves, with special emphasis on ionospheric effects.

Radio Science is published by the Bureau in cooperation with the U.S. National Committee of the International Scientific Radio Union (URSI). D. D. Crombie, Acting Chief of the Low Frequency Research Section, Ionosphere Research and Propagation Division of the Boulder Laboratories, served as editor for the special January inaugural issue. Mr. Crombie also served as chairman of the Technical Program Committee for the Symposium.

Although the earliest long-distance communications were performed with the aid of very-low-frequency (3 to 30 kc/s) radio waves, these frequencies fell into relative disuse in the middle 1920's. This situation remained until about the 1950's when some of the attractive features of VLF communication, such as relative immunity to ionospheric disturbances, remarkably high phase stability, and relatively deep penetration into sea water, began to outweigh the disadvantages for certain purposes. Some of the present interesting applications of VLF transmissions are to long-range navigational aids, to the dissemination of frequency standards, and to the study of perturbations, both natural and manmade, of the lower ionosphere.

In 1957 the first conference devoted to VLF propagation was held in Boulder. Because of the considerable success of this meeting, and of the great advances

made in theoretical problems in this field, a second symposium was held at the NBS Central Radio Propagation Laboratory, Boulder, Colo., during August 12, 13, and 14 of 1963. Of the nearly 50 papers presented during the symposium, some 20 are included either fully or in summary form in the January issue of *Radio Science*. It is expected that some of the other papers presented at the symposium will appear in subsequent issues.

The papers included in this special issue show the considerable strides that have been made, both experimentally and theoretically, since the earlier symposium. Techniques for the observation of variation in phase delay are now well established and are being widely used. It has now been definitely confirmed that non-reciprocal propagation exists, and earlier estimates of the magnitude of this effect have been verified. The theoretical papers were concerned with the consequences of recognizing that the ionosphere is not sharply bounded, and included calculations relating to the effects of the earth's magnetic field on reciprocity. Another group of papers was concerned with the relatively new field of the effect of high-altitude nuclear explosions on the propagation of VLF radio waves.

Radio Science will present research papers, as well as occasional survey articles, in radio propagation, communications, and radio science generally. It will serve as the principal publication outlet for the research of the NBS Central Radio Propagation Laboratory and the scientific activities of the U.S. National Committee of URSI. It will also carry selected papers from the NBS Radio Standards Laboratory and invited papers from recognized authorities in the field of radio science.

Publications of the National Bureau of Standards

Periodicals

- Technical News Bulletin*, Volume 48, No. 1, January 1964. 15 cents. Annual subscription: \$1.50; 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.
- CRPL Ionospheric Predictions* for April 1964. Three months in advance. Number 13, issued January 1964. 15 cents. Annual subscription: \$1.50; 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.
- Journal of Research of the National Bureau of Standards*
- Section A. *Physics and Chemistry*. Issued six times a year. Annual subscription: Domestic, \$4; foreign, \$4.75.
- Section B. *Mathematics and Mathematical Physics*. Issued quarterly. Annual subscription: Domestic, \$2.25; foreign, \$2.75.
- Section C. *Engineering and Instrumentation*. Issued quarterly. Annual subscription: Domestic, \$2.25; foreign, \$2.75.
- Section D. *Radio Science*. Issued monthly. Annual subscription: Domestic, \$9; foreign, \$11.50.

Current Issues of the Journal of Research

- J. Res. NBS 68A (Phys. and Chem.)*, No. 1 (Jan.-Feb. 1964). Fast neutron dose measurements for a D-D source in water. W. B. Beverly and V. Spiegel, Jr.
- X-ray spectrometric analysis of noble metal dental alloys. B. W. Mulligan, H. J. Caul, S. D. Rasberry, and B. F. Scribner.
- The first spectrum of manganese, Mn I. M. A. Catalán, W. F. Meggers, and O. Garcia-Riquelme.
- Transition probabilities of forbidden lines. R. H. Garstang.
- Frank-Condon factors to high vibrational quantum numbers III: CN. R. W. Nicholls.
- Infrared absorption spectrum of nitrous oxide (N_2O). From 1830 cm^{-1} to 2270 cm^{-1} . E. K. Plyler, E. D. Tidwell, and A. G. Maki.
- An absolute light scattering photometer: II. Direct determination of scattered light from solutions. D. McIntyre.
- High pressure microscopy of the silver and cuprous halides. A. Van Valkenburg.
- Lattice parameters and lattice energies of high-pressure polymorphs of some alkali halides. C. E. Weir and G. J. Piermarini.
- Calculation of the higher order dipole-dipole effect in paramagnetic crystals. P. H. E. Meijer.
- Second and third virial coefficients for hydrogen. R. D. Goodwin, D. E. Diller, H. M. Roder, and L. A. Weber.
- Heats of solution, transition, and formation of three crystalline forms of metaboric acid. M. V. Kilday and E. J. Prosen.
- Radio Sci. J. Res. NBS/USNC-URSI*, Vol. 68, No. 2, Feb. 1964.
- Generation of an electromagnetic pulse by an expanding plasma in a conducting half-space. A. P. Stogryn and R. N. Ghose.
- Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half-space, part II. S. W. Maley and R. J. King.
- Capacitor type biconical antennas. J. Galejs.
- Simulated angular response patterns for transhorizon propagation. J. W. Strohbehn and A. T. Waterman, Jr.
- Radio-star scintillations from ionospheric waves. J. W. Warwick.
- Ionosonde studies of some chemical releases in the ionosphere. J. W. Wright.
- Diurnal changes and transmission time in the arctic propagation of VLF waves. W. T. Blackband.
- Geometrical optics convergence coefficient for the whistler case. J. H. Crary.
- Comments on a paper 'Collisional Detachment and the Formation of an Ionospheric' by E. T. Pierce, H. R. Arnold.

- The quasi-longitudinal approximation in the generalized theory of radio wave absorption. R. F. Benson.
- Diurnal phase variation of VLF waves at medium distances. H. Volland.
- Application of diffractions by convex surfaces to irregular terrain situations. H. T. Dougherty and L. J. Maloney.
- Effect of lossy earth on antenna gain. R. J. Coe and W. L. Curtis.
- Propagation of radio waves with frequency 99.9 Mhz as a function of the vertical structure of the atmosphere derived from daily radiosonde observations. G. P. A. Braam.

Other NBS Publications

- Methods for the dynamic calibration of pressure transducers, J. L. Schweppe, L. C. Eichberger, D. F. Muster, E. L. Michaels, and G. F. Paskusz, NBS Mono. 67 (Dec. 12, 1963), 60 cents.
- Radioactivity, Recommendations of the International Commission on Radiological Units and Measurements, NBS Handb. 86 (Nov. 29, 1963) 40 cents. (This publication supersedes parts of H78. Handbooks 84 through 89 extend and largely replace H78.)
- Weights and measures standards of the United States, a brief history, L. V. Judson, NBS Misc. Publ. 247 (Oct. 1963), 35 cents. (Supersedes Sci. Paper No. 17 and Misc. Publ. 64)
- Survey of the literature on safety of residential chimneys and fireplaces, H. Shoub, NBS Misc. Publ. 252 (Dec. 17, 1963), 15 cents.
- Grading of a diamond powder in sub-sieve sizes, CS261-63, 10 cents. Supersedes in part CS123-49)
- Vises (machinists' and other bench-mounted vises), SPR 229-63, 10 cents. (Supersedes R229-48)
- Mean electron density variations of the quiet ionosphere No. 12, February 1960, J. W. Wright, L. R. Wescott, and D. J. Brown, NBS Tech. Note 40-12 (Dec. 6, 1963), 35 cents.
- Photometry of projectors at the National Bureau of Standards, L. Chernoff, NBS Tech. Note 198 (Dec. 17, 1963), 25 cents.
- A technique for extrapolating the 1 kc values of secondary capacitance standards to higher frequencies, R. N. Jones, NBS Tech. Note 201 (Nov. 5, 1963), 15 cents.
- Thermodynamic property values for gaseous and liquid carbon monoxide from 70 to 300 °K with pressures to 300 atmospheres, J. G. Hust and R. B. Stewart, NBS Tech. Note 202 (Nov. 30, 1963), 60 cents.
- BOUMAC, A macro-programming system for scientific computation, J. H. Devenney and J. J. Sopka, NBS Tech. Note 203 (Dec. 18, 1963), 30 cents.
- Calculations of the field near the apex of a wedge surface, J. R. Wait and C. M. Jackson, NBS Tech. Note 204 (Nov. 21, 1963), 45 cents.
- The normal phase variations of the 18 kc/s signals from NBA observed at Frankfurt, Germany, A. H. Brady, A. C. Murphy, and D. D. Crombie, NBS Tech. Note 206-1 (Dec. 8, 1963), 25 cents.
- Solar heating, radiative cooling, and thermal movement—their effects on built-up roofing, W. C. Cullen, NBS Tech. Note 231 (Dec. 16, 1963), 25 cents.

Publications in Other Journals

- This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.*
- Natural electromagnetic field fluctuations in the 3.0 to 0.02 cps range, W. H. Campbell, Proc. IEEE 51, 1337-1342 (Oct. 1963).
- Current development in an electronically scanned antenna, H. V. Cottony, Proc. Symp. Electromagnetic Theory and An-

- tennas, Copenhagen, June 25-30, 1962, pp. 1289-1294 (Pergamon Press, Oxford, London, 1963).
- Airglow research, F. E. Roach, *Trans. Am. Geophys. Union* **44**, No. 2, 431-432 (June 1963).
- Velocity-depth relationship in microelectrophoresis cell for asphaltenes in nitromethane, J. R. Wright and R. R. Minesinger, *J. Colloid Sci.* **18**, 802-804 (Oct. 1963).
- Galvanostametry, a new technique based on the negative pressure of liquids, for investigating electrochemical phenomena at an electrode, J. Sligh and A. Brenner, *J. Electrochem. Soc.* **110**, No. 11, 1136-1142 (Nov. 1963).
- Some results of a new method for obtaining ionospheric $N(h)$ profiles and their bearing on the structure of the lower F region, A. K. Paul and J. W. Wright, *J. Geophys. Res.* **68**, No. 19, 5413-5420 (Oct. 1, 1963).
- Electrical resistance-strain characteristics of thin evaporated metal films, R. L. Parker and A. Krinsky, *J. Appl. Phys.* **34**, No. 9, 2700-2708 (Sept. 1963).
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Thermal Radiation Symposium Proceedings

The *Proceedings* of the Symposium on Measurement of the Thermal Radiation Properties of Solids held in Dayton, Ohio, September 5, 6, and 7, 1962, have been published by the National Aeronautics and Space Administration. The meeting was sponsored by NASA, the National Bureau of Standards, and the Aeronautical Systems Division of the U.S. Air Force. Joseph C. Richmond of NBS edited the *Proceedings*.

A very great increase in the need for data on the thermal radiation properties of solids as a consequence of the national space program was the main force in establishing the Symposium. The overall objectives of the meeting were to afford (1) an opportunity for workers in the field to describe the equipment and procedures currently in use for measuring the thermal radiation properties of solids, (2) an opportunity for constructive criticism of the material presented, and (3) an open forum for discussion of mutual problems.

It was also the hope of the sponsors that the published *Proceedings* would serve as a valuable reference on measurement techniques for evaluating the thermal radiation properties of solids, particularly for those with limited experience in the field.

The first session of the Symposium was devoted to a discussion of temperature measurement problems because of the strong dependence of emitted flux on temperature. The remaining four sessions were devoted to discussions of measurement of thermal properties in each of four temperature ranges: Session II, low temperatures (0 to 200 °K); Session III, satellite temperatures (200 to 450 °K); Session IV, moderately high temperatures (450 to 1400 °K); and Session V, high temperatures (above 1400 °K).

The *Proceedings, Measurement of Thermal Radiation Properties of Solids* (NASA SP-31) are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for \$3.50.

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